Title of Investigation:

Remotely Sensing Weak Magnetic Fields via High-Resolution Infrared Spectropolarimetry

Principal Investigator:

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Other In-house Members of Team:

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Other External Collaborators:

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Initiation Year:

FY 2005

Aggregate Amount of Funding Authorized in FY 2004 and Earlier Years:

$0

Funding Authorized for FY 2005:

$31,000

Actual or Expected Expenditure of FY 2005 Funding:

Contracts: $7,500 to Karl Lambrecht Corp. for infrared wave plates; $16,000 to Newport Corp. for optical mounts, rotary mounts, motion controller; $7,500 to Specac for high-efficiency wire-grid polarizer and mount

Status of Investigation at End of FY 2005:

To be continued in FY 2006 by whatever means are available

Expected Completion Date:

September 2006

Purpose of Investigation:

To investigate solar system objects with weak magnetic fields, we use spectra of the light that they emit at different polarizations. Most of the bodies in our solar system have magnetic fields whose strengths are too low to be monitored remotely by way of Zeeman splitting of emission line–the separation of emission lines into polarized components by magnetic fields. If the magnetic field is not strong enough to split the line, the line's dipole moment may still be sensitive to the magnetic field's strength and direction. This type of reaction of the dipole to the magnetic field is known in atomic and molecular physics as the Hanle effect. Since the degree of polarization is dependent on both the magnetic field and the line's emission lifetime, it has been used in the past to measure atomic/molecular lifetimes in the laboratory by varying a known magnetic field and measuring the resultant degree of polarization. Likewise, if the lifetime is known, then the magnetic-field properties can be deduced from the measured degree of polarization. This technique is sensitive to a broad range of magnetic-field strengths depending on the lifetime of the emission line being monitored. Thus, even weak magnetic fields can be measured. The usefulness of this technique can be demonstrated with Mars, whose weak magnetic field has been extensively mapped by the Mars Global Surveyor (MGS) mission.

Accomplishments to Date:

An infrared polarization analysis package (IPAP) has been designed and constructed for use with the Cryogenic Echelle Spectrograph (CSHELL) at the NASA Infrared Telescope Facility (IRTF). IPAP consists of a rotating half-wave plate, followed by a wire-grid polarizer whose optical axis is fixed at a specified angular position. The half-wave plate rotates the polarization of the incoming radiation, which is then analyzed with the wire-grid polarizer. To ensure there are no artifacts in the data due to the ruling direction on the spectrometer's grating, the radiation passes through a quarter-wave plate before entering CSHELL. The quarter-wave plate circularizes the linear radiation from the analyzer, thereby simulating isotropic radiation incident on CSHELL's grating. The wave plates are optimized for 4.6 microns, corresponding to an emission from carbon monoxide previously observed in the Martian atmosphere using scalar (unpolarized, i.e., intensity only) spectroscopy with this same spectrograph/telescope combination. The half-wave plate was mounted in a stepper-motor-controlled rotary stage so that the angle of the plate's optical axis could be moved through a set of angles relative to the direction of the analyzer's optical axis. This allows us to obtain the entire set of Stokes parameters for a given spatial position of the spectrometer's slit on the planet.

In August 2005, we submitted a successful proposal to the IRTF Telescope Allocation Committee, requesting time on the IRTF to observe Mars with our IPAP with CSHELL during maximum opposition, the most favorable time for these types of observations. We were awarded four half-nights of observing time from Nov. 17–20, 2005. Principal Investigator J. Allen traveled to IRTF to install and operate IPAP and oversee the observational campaign. Two other members of the observing team—Co-Investigators M. DiSanti and Tilak Hewagama (University of Maryland)—participated in the observations via remote (Polycom) hookup from Goddard's Building 2. This arrangement worked quite well and significantly reduced travel costs. It was the PIs' first observing run at the IRTF and the value of their participation cannot be overstated since they have extensive experience with observing at the IRTF both onsite and remotely. The campaign was a complete success. After some relatively minor mechanical modifications at the IRTF, IPAP was easily installed in the enclosure connecting the telescope to CSHELL and the unit operated as expected. A significant quantity of data was acquired despite weather-related issues on one of the nights.

Planned Future Work:

The acquired data are in raw form and will have to be reduced and corrected before any definitive comparisons can be made with the MGS measurements. We are in the process of developing the programs necessary to perform the data-reduction tasks and to describe the observations in the context of the Martian atmospheric-surface system. We hope to obtain support from the Planetary Astronomy or Planetary Atmospheres Program to support these efforts.

Key Points Summary:

Project's innovative features: We have successfully developed IPAP and demonstrated the ability to use it with CSHELL at the IRTF to acquire spectropolarimetric data. According to Co-investigator A. Tokunaga, who is both the IRTF Director and the developer of CSHELL, this is the first time this has been done with that instrument at that facility. To our knowledge, this also is the first attempt to apply Hanle-effect measurements of line emissions to determine magnetic-field properties of a solar system object other than the Sun.

Potential payoff to Goddard/NASA: Development and implementation of molecular spectropolarimetry for remote sensing of weak magnetic fields will make routine observational programs possible, just as scalar spectroscopies and imaging make it possible to observe atmospheric composition and surface structure, for example. The technique is a cost-effective way to survey magnetic fields of different objects, as well as make synoptic measurements of those that have not been or are not being orbited by spacecraft. The information obtained via this method can provide "ground truth" for *in situ* magnetometer measurements and will facilitate planning of future missions.

The criteria for success: The main criterion for success of this activity will be marked by the comparison of the reduced and processed spectropolarimetric data acquired here with the results form the *in situ* measurements made by the magnetometer/electron reflector instruments (MAG/ER) instrument aboard MGS.

Technical risk factors: As noted above, this is the first time measurements of this type have been made with CSHELL at the IRTF. It also is the first application of the Hanle-effect technique to take spectropolarimetric measurements of magnetic field properties in planetary objects. Acquisition of the raw data was successful as demonstrated by our recent observing campaign. However, interpretation of the results depends on the development of the appropriate programs for data reduction and modeling of the final results. Uncertainty exists as to how well our remote measurements will compare with the existing results from the MAG/ER instrument. These issues will take time to address, but there are no apparent major stumbling blocks at this point.

No remote measurements of this type have ever been performed and we are attempting to do it by combining two techniques both of which are relatively new. This entails substantial risk for quick success. We have made significant progress in developing each of the two techniques separately, but have not yet been successful in using them together in a single measurement. We propose to continue the effort with support from the Planetary Astronomy Program.